TESLA

Efficient Management of System Strength

Tesla response to AEMC Draft Determination (ERC0300)

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June 2021

James Hyatt
Australian Energy Market Commission
Lodged online

17/06/2021

RE: Efficient Management of System Strength - Draft Determination (ERC0300)

Dear James,

Tesla Motors Australia, Pty Ltd (Tesla) welcomes the opportunity to provide a submission to the AEMC's draft determination on the efficient management of system strength on the power system. Tesla remains committed to working with market bodies to improve power system security and reliability outcomes in the National Energy Market (NEM) in a manner that is efficient for consumers, timely for ongoing secure system operations, and enables the transition to sustainable energy. We note the real and immediate need for action to improve the current system strength 'do no harm' frameworks in the NEM and agree with the AEMC that system strength is at risk of rapid deteriorating as the integration of renewables accelerates. Accordingly, Tesla supports the AEMC's intent for system strength to be provided through a structured procurement mechanism, ahead of potential markets being developed (as per the ESB's Post 2025 process).

To date, battery storage has been mostly recognised for the value it provides in managing frequency stability and restoration - providing premium contingency and regulation frequency services across the NEM since the introduction of Hornsdale Power Reserve in 2017. However, as familiarity with power electronics and grid-forming inverters grows, we encourage the AEMC to embed a future focused framework that also recognises the value that 'non-synchronous' assets such as grid-forming battery storage can provide in terms of positive contribution to system strength, voltage stabilisation and inertia. Tesla supports AEMC formalising its more appropriate definition of system strength that focuses on voltage waveform stabilisation, rather than relying on measurements limited to fault current levels.

Specific to the new system strength framework, Tesla recommends:

1. **Supply side:** New obligations (based on voltage waveform) on TNSPs need to recognise and value the benefits of non-network solutions. This requires an alternative to and/or update of the RIT-T
2. **Demand side:** Access standards and system strength quantities (SSQ) need to reflect the capabilities of grid forming inverters (i.e. SSQ=0) to prevent unnecessary connection barriers
3. **Coordination:** Cost recovery will be most efficient by enabling multiple services to be provided from the same asset, and embedding technology neutral procurement principles that remove any inherent biases to capex or network-based solutions (e.g. synchronous condensers)

Tesla looks forward to continued engagement on these items.

Sincerely,

Emma Fagan - Head of Energy Policy and Regulation
Tesla Energy

Executive Summary

1. **AEMC should focus on creating a framework that can recognise the role of battery energy storage systems (BESS) providing system strength**
    - Grid-forming battery storage can provide all equivalent services in respect to system strength, with additional network, system and commercial benefits – enabling a rapid (yet secure and affordable) transition to 100% renewable energy
    - Tesla is currently working with AEMO to demonstrate the technical feasibility of its batteries providing essential systems services such as virtual inertia and system strength in the NEM. It would be an oversight for the AEMC to introduce a framework that fails to encourage the adoption of new technology locking-out innovation benefits and locking-in higher costs for consumers. As such, on the demand-side we support grid-forming BESS having a system strength quantity (SSQ) of 0
    - On the supply-side, Tesla supports a technology neutral definition of system strength that focuses on voltage waveform stabilisation, rather than historical measurements limited to fault current levels. This will ensure grid-forming battery storage and re-turning of renewable inverters can participate on an equal footing and maximise the supply pool of solutions broader than traditional network asset solutions (e.g. synchronous condensers)
    - The PSCAD modelling process being currently undertaken by Powerlink provides an instructive example of the capabilities of non-network proponents to support additional system strength in Queensland. It would be inequitable to allow other TNSPs to continue to use fault level as a proxy in a way that limits the assessment of other voltage stabilisation technologies

2. **New regulatory investment test (RIT) frameworks are needed to facilitate non-network options such as BESS, before the system strength guidelines can be successfully applied**
    - The RIT is no longer fit for purpose – the process takes far too long to be practical, and the current application of the 'total economic cost' framework fails to recognise today's technology and commercial models. We recognise the attraction of drawing on existing regulatory frameworks, but there are major costs associated with doing so
    - Non-network options remain consistently undervalued in the RIT-T framework.To Tesla's knowledge, there have been no successful non-network solutions selected as the preferred option under any RIT-T to date. This is because the RIT-T fails to value the full suite of benefits BESS provide, and forces a total economic cost approach that inflates their cost relative to alternatives
    - Even if the new system strength rules recognise the capabilities and benefits of BESS providing system strength services, network companies may face additional barriers in valuing these benefits based on the RIT assessment guidelines, undermining the scheme's benefits: delaying the connection process, unfairly disadvantaging the value proposition of BESS, and adding unnecessary costs to the total system (with less efficient solutions ultimately progressed). These barriers would also frustrate the proposed interlinkages with the UCS and SSM
    - Whilst broader than this single rule change, the AEMC must still expedite work with the AER to update all RIT-T guidelines and frameworks that currently impose barriers for non-network options, to ensure the full benefits of an efficient system strength rule change can be captured. Alternatively, the new system strength framework should avoid deferring to the RIT-T until it is fit for purpose. This will have positive flow on effects for all future network led investments, driving more efficient expenditure and lowering costs for all consumers
    - State governments are already implementing bespoke frameworks to circumvent these issues – e.g. National Electricity (Victoria) Amendment Act 2020; NSW Transmission Efficiency Test – which risks inconsistent and disjointed investment frameworks if the RIT isn't updated quickly

RIT framework barriers for non-network options

Efficient procurement of system strength requires RIT updates

- Batteries can provide all essential energy, system and network services. This ability is already being demonstrated across a suite of services with premium speed and accuracy for grid operators, including for system strength
- However, non-network options are still undervalued in the RIT framework. We understand some barriers may relate directly to the framework itself (see 4 key issues on right), whilst others arise due to misinterpretation and unfamiliarity that network service providers may have with the assessment of non-traditional solutions such as battery storage. We believe the AEMC must work closely with the AER to help address both
- Properly assessing the full value stack and ensuring analysis captures total economic benefits (not just costs), will accelerate the uptake of storage, and support new system strength procurement rules
- **Without new RIT frameworks, there will be a disconnect between the efficient outcomes of the system strength rule change, and the ability for network providers to assess and select non-network solutions as preferred options for providing system strength**

Non-network option barriers in RIT-T

OPTIONALITY

- Part of framework but benefits rarely captured
- Key part of value proposition for non-network options relative to network assets - rapid deployment, modularity (scale up or down)
- Flexibility increasingly important with uncertainty in load and generation forecasts increasing due to transition

MARKET BENEFITS

- BESS proven ability to reduce prices in wholesale energy and FCAS markets
- Benefits excluded due to being 'wealth transfers', but this ignores benefits from improved liquidity and/or the removal of price distortions
- Likely reduced costs on other parties and consumers (e.g. back-up plant directed on)

ANCILLARY SERVICES

- Battery storage projects see most value realised in FCAS markets
- RIT-Ts typically only model wholesale energy changes occurring in dispatch - considering FCAS a negligible class of market benefit
- Unclear how ESS and system strength would be captured

COST ASYMMETRY

- Battery storage can provide multiple services to multiple parties (system strength + energy, FCAS, inertia, FFR…etc)
- AER's guidelines enforce 'total capital cost' is captured, regardless of ownership
- However, this is not balanced by 'total benefits' also being captured – so BESS severely disadvantaged

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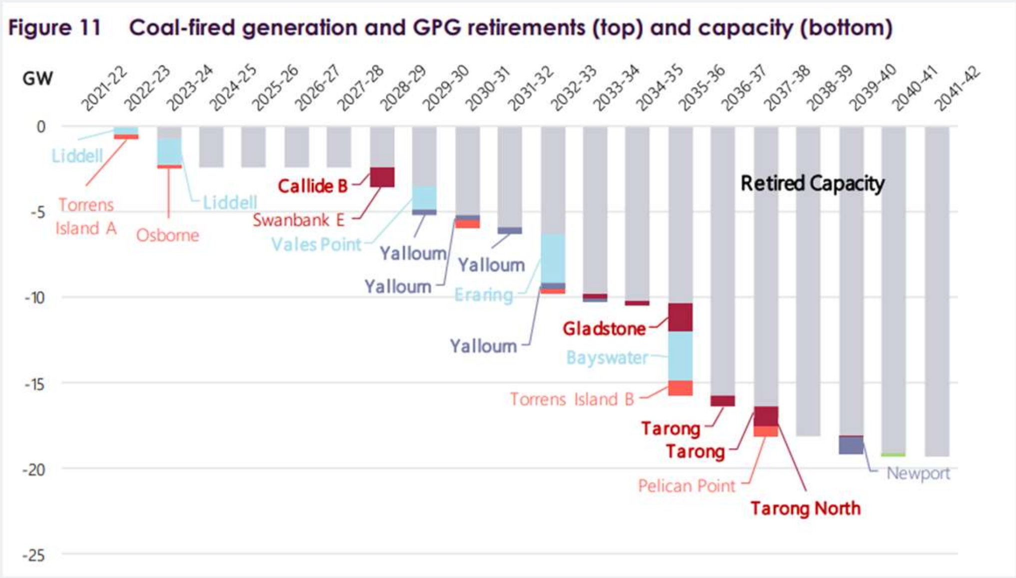
The role of battery storage providing system strength

Tesla's Mission

Managing the transition to 100% renewable energy

- Australia's energy supply is rapidly moving away from thermal generation into much higher penetrations of renewables, where up to 100% of electricity is supplied by zero emissions technologies.
- This rapid transition will require careful planning to ensure that there is minimal impact on energy system security and reliability, while delivering lowest possible costs for consumers.
- There are a number of services that need to be provided in order to support the transition to ensure reliability and grid security, while managing emissions. They include frequency control, inertia and system strength. These services will support high penetrations of renewable energy in a manner that ensures the future electricity supply in Australia is reliable, secure and affordable.
- Provided the right incentives are in place, and capabilities of modern technologies are properly valued, each of the services needed to manage this transition can be provided with technology available today – including battery energy storage.



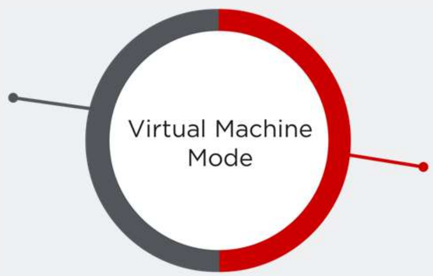
Coal retirement rates: AEMO 2020 Integrated System Plan

Battery Storage in the future Australian Electricity Mix

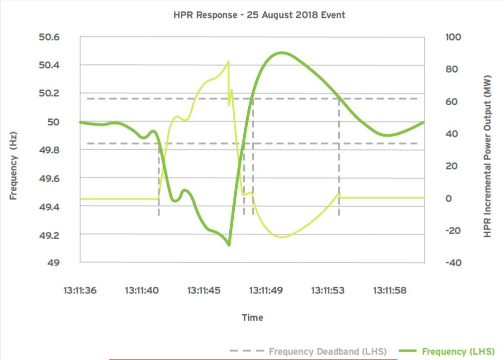
Managing the transition to 100% renewable energy

- Batteries are uniquely placed and flexible enough to provide a range of the critical system security services necessary to support this transition to 100% renewable energy.
- A major benefit of battery storage is the ability to optimise for different services for different geographical locations and at different points in time.
- The combination of providing system strength, virtual inertia and frequency support, as well as the ability to support peak and negative energy events, means that battery storage can support all renewable energy futures.

SYSTEM STRENGTH



INERTIA



FREQUENCY RESPONSE

Constellation of System Services from Tesla's battery storage technology

System Service provision - comparison across assets / technologies:

Service \ Asset	Grid-forming battery	Synchronous Generator (e.g. Gas / Hydro)	Variable Renewable Generator	Static VAR Compensator (SVC)	Synchronous Condenser (Syncon)	Static Synchronous Compensator (STATCOM)
Inertia	✓ (red)	✓	✓* (light)		✓	✓ (light)
Voltage stability	✓	✓	✓	✓	✓	✓
System strength	✓ (red)	✓			✓	
Harmonic dampening	✓ (red)			✓ (light)	✓ (light)	✓
Frequency Stability	✓	✓	✓			
Fast Frequency Response	✓		✓* (light)			
Stand-alone / system re-start services	✓ (red)	✓				

✓ (light) *Some / minimal functionality – e.g. *some new wind farms with appropriate control systems*

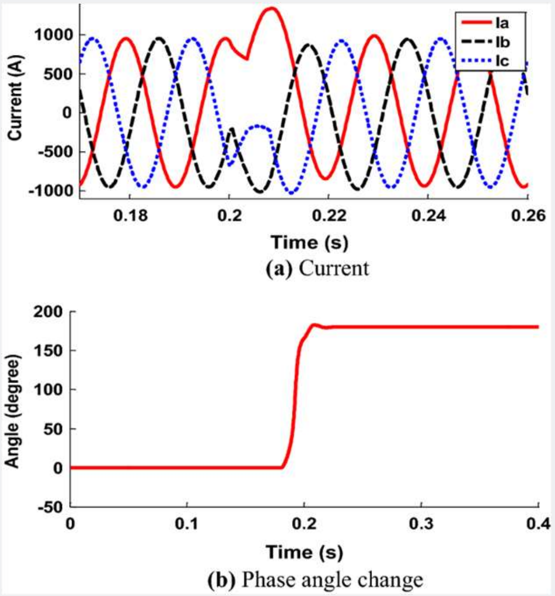
✓ *Standard functionality*

✓ (red) *with grid-forming inverter*

Background: Grid Following Inverters

System Strength and Grid Following Inverters

- Grid following inverters are also known as current sources – they are unable to generate their own voltage waveform and must adhere to the voltage waveform in the grid.
- They inject current at an angle that follows the measured voltage angle, through the operation of a phase locked loop (PLL).
- They require a minimum level of system strength to work reliably. The grid's voltage signal becomes harder to follow when further away from a voltage source.
- Following a fault, a grid following inverter must re-lock onto the grid quickly to ensure stable control. Under low system strength conditions, the phase angle change before and after a fault makes this process different, potentially leading to voltage stability issues and oscillations



Grid following inverters following a disturbance
https://link.springer.com/article/10.1007/s00202-019-00896-5

Tesla – Virtual Machine Mode

Inverter based system strength and virtual inertia

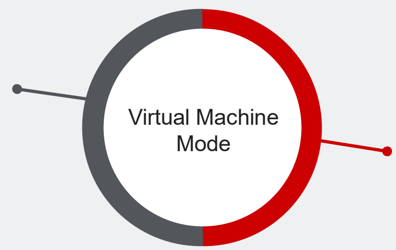
- Tesla Inverters operating in Virtual Machine Mode can provide inertia and fast acting voltage smoothing to support regions of low system strength. The Rotating Machine Model component of Virtual Machine Mode responds to fluctuations in voltage with a countervailing current response. For example, if voltage suddenly drops, the machine model will inject reactive current temporarily in response. This can smooth and stabilise voltage in regions of low system strength.
- As the inverter's inertial response is created by the inverter controls, it can be modified based on the grid's needs (unlike traditional generators that have a fixed inertia constant based on their physical characteristics).
- The virtual machine model is a flexible feature that can be enabled or disabled as required. Its parameters such as inertia constant and impedance are fully configurable and can be tuned to obtain the desired dynamic behaviour for the grid. The inertia constant of a Tesla battery can be configured from 0.1 to 50+MW.s/MVA. Similar is possible for system strength applications.
- In addition, inverter based technologies can utilise their short term overload capability to provide fault current contribution, improving the short circuit ratio at a connection point

Tesla Inverter Virtual Machine Mode

A Tesla inverter can operate in Virtual Machine Mode combining the benefits of a configurable current source and a rotating machine model (voltage source) to support grid stability in regions of low system strength.

Configurable Current Source (Grid-Following)

- Real power dispatch
- Reactive power dispatch
- Frequency support
- Voltage support



Rotating Machine Model (Grid-Forming)

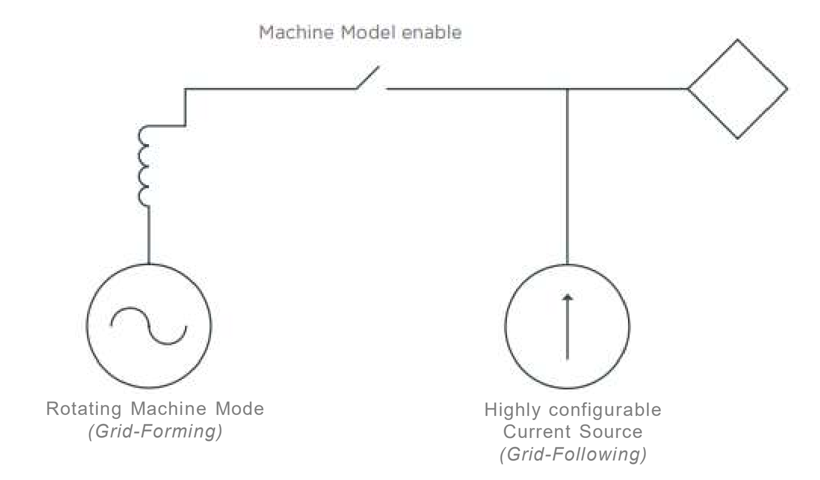
- Virtual Inertia
- Dynamic voltage smoothing
- System strength support
- Harmonic Dampening
- Standalone operation

Tesla – Virtual Machine Mode

Inverter based system strength and virtual inertia

- Virtual Machine Mode is a feature implemented on Tesla inverters that mimics the behaviour of a traditional rotating machine. The virtual machine component runs in parallel with the conventional current source component.
- The virtual machine is a blended mode that brings dispatchability of a current source operating in parallel with the stability benefits of a voltage source.
- Like more traditional inverters, under stable system conditions, the inverter's behaviour is driven by the current source component. The inverter charges and discharges in accordance with commands received from the operator.
- If there is a grid disturbance, the rotating component responds by producing a reactive current in response to changes in voltage and producing an active power response proportional to the rate of change of frequency (RoCoF).
- Though these features can be provided by current-source inverters in response to a predefined feedback control mechanism, the rotating component in Tesla's batteries can respond on a sub-cycle basis – responding to phase angle changes (within << 10ms) rather than root-means-squared (RMS) values (within 100ms) – mimicking the electromagnetics of a synchronous generator, but with the additional benefit of flexibility and control over the degree of the response.

Tesla Inverter Virtual Machine Mode:
A Tesla inverter can operate in Virtual Machine Mode with a configurable current source operating in parallel with a rotating machine model (grid forming voltage source).



Virtual Machine Mode representation

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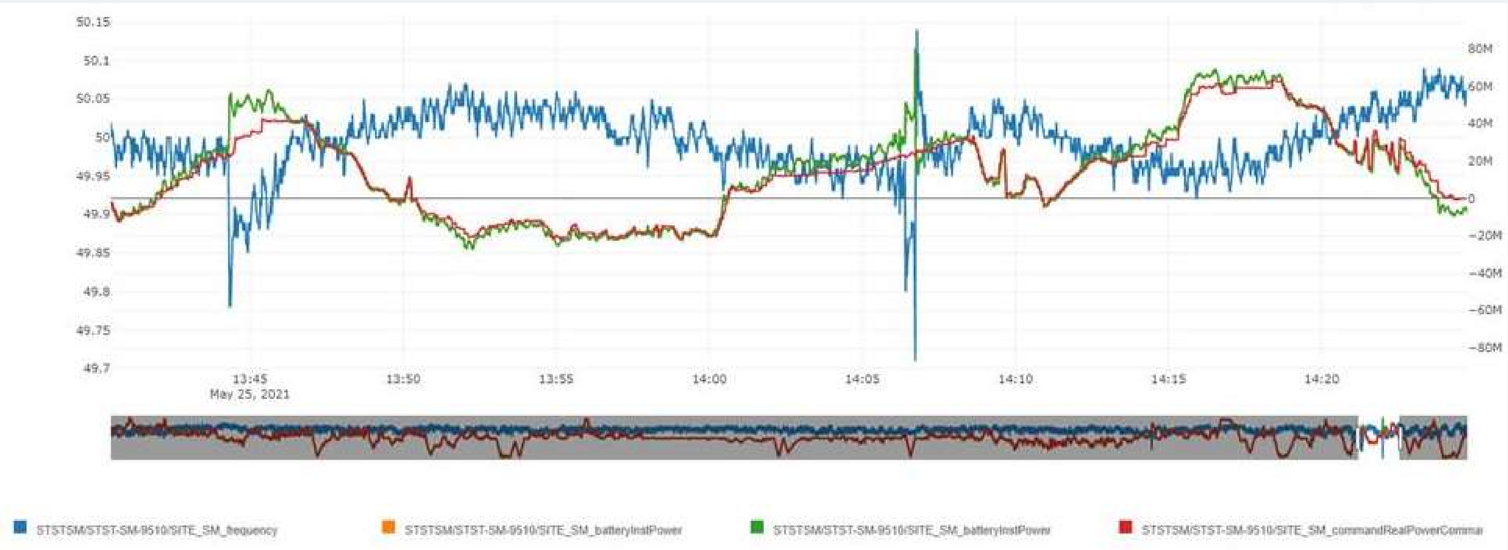
Appendix: Case studies

Hornsdale Power Reserve - Expansion

- In 2020, Neoen and Tesla received backing from ARENA, CEFC and the SA Grid Scale Storage Fund to expand Hornsdale Power Reserve by 50% to 150 MW / 192 MWh – maintaining its crown as Australia's largest battery while expanding its suite of system support services.
- Hornsdale will be the first battery in the NEM to operate in Virtual Machine Mode, proving its capability as a provider of system strength, inertia services, voltage control and fast frequency response.
- Through this trial, Tesla intends to have storage recognised by AEMO as having a positive, rather than a neutral contribution to system strength.
- Once expanded, the Hornsdale Power Reserve could provide up to 3,000MWs of inertia to the local South Australian grid.

Callide C Power Station Event

Primary Frequency Response

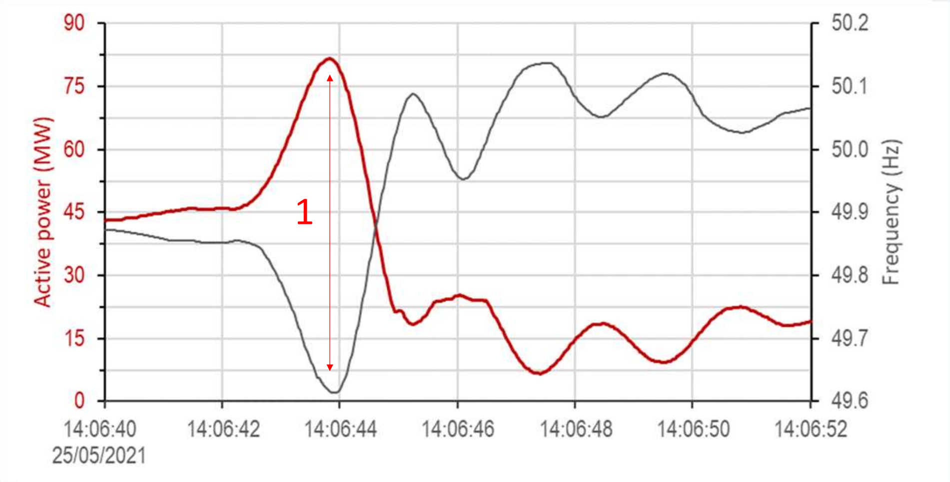


- Callide C event on 25 May 2021 resulted in a “multiple contingency event” as per the frequency operating standard.
- This resulted in unique datasets for Hornsdale Power Reserve both in demonstrating primary frequency response and in demonstrating the ability of a BESS to provide inertia.

Callide C Power Station Event

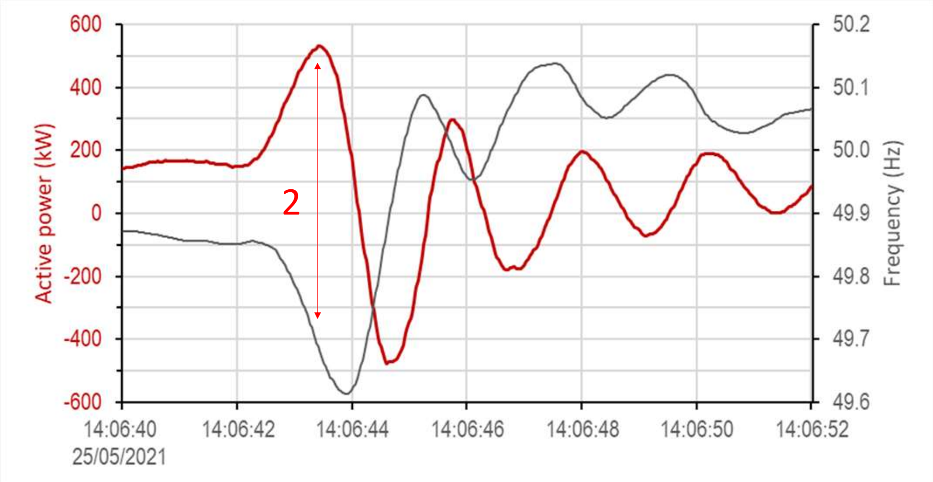
Inertial Response

Site Response



- Active power response proportional to frequency
- Response commences once frequency departs the configured deadband
- Maximum power response when frequency reaches lowest point (nadir)

Virtual Machine Mode Enabled Inverter Response

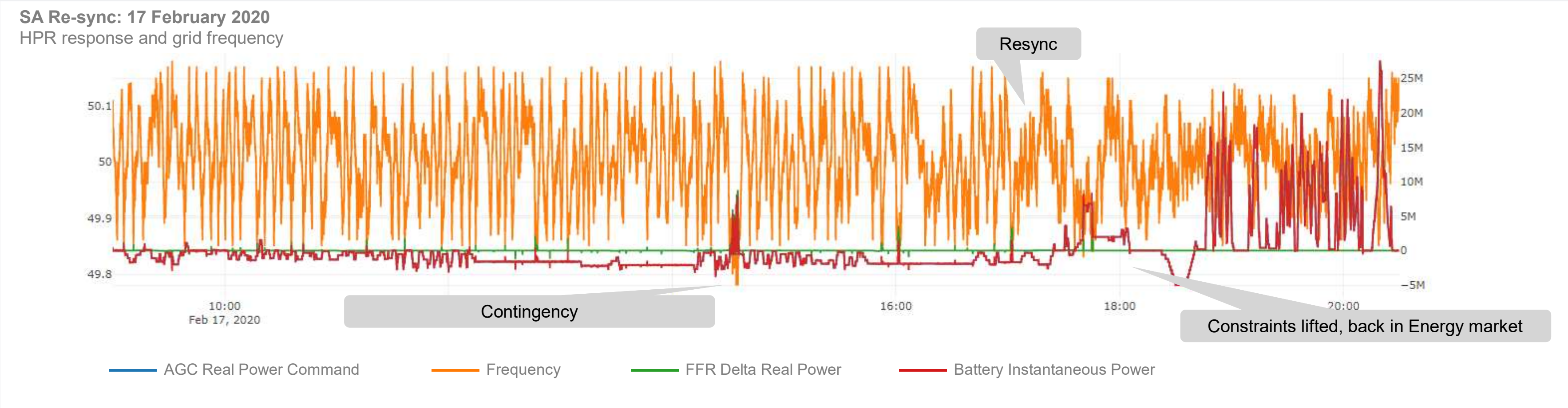


- Active power response proportional to Rate of Change of Frequency
- Response commences prior to frequency departing configured deadband
- Maximum power response when frequency is changing the fastest
- Stabilising effect to dampen overshoot of corrections by broader system

Notes: Virtual Machine Mode is enabled on 2 HPR inverters; chart shows measured response to system event on 25 May 2021; metered frequency data has been up-sampled from 200ms measurements to align with 25ms power data sampling rate.

Frequency stability

SA islanding event



- The South Australian separation event provides an instructive example of the existing capabilities of battery systems to respond rapidly to provide grid support (transitioning from AEMO AGC signal to support the islanded SA grid), before playing a critical role in ensuring a smooth and seamless resynchronization could be achieved between SA and the wider NEM network
- During islanding, AEMO constrained SA batteries to zero MW output but allowed 50% state of charge to allow provision of raise and lower contingency FCAS
- Data also highlights that frequency management during the islanded and NEM connected periods were not remarkably different
- It demonstrates technical feasibility in providing system security service today, and the critical role batteries will continue to play going forward in a high renewables NEM